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Soil Organic Carbon Pools in Urbanizing Hilly State of India

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ABSTRACT

Urbanization results in the dramatic change in the land use, which impacts soil organic carbon (SOC) stocks in topsoil. The dynamic changes in soil organic carbon pools have significant implications on regional and global carbon balances. The aim of this study was to examine the impact of urbanization on SOC stocks in an urbanized area of Kangra district with varying degree of urbanization under north western Himalayas, India. Soil samples of both urbanized and control areas were collected from three sites namely Dharamshala, Palampur and Baijnath-Paprola. Impact of urbanization on soil organic carbon storage was evaluated and soil carbon stock was found to be varied significantly among different urban areas. The highest soil carbon stock (26.48 Mg C ha^{-1}) was recorded in Municipal Corporation which was significantly higher than Municipal Council (23.84 Mg C ha^{-1}) and Nagar Panchayat (22.24 Mg C ha^{-1}). All the urban sites accumulated more SOC than countryside areas which has challenged the assumption of degrading ecosystem services by urban areas. Henceforth, it is suggested that in order to support enhanced carbon sequestration in soil mapping and periodic estimation of soil organic carbon stocks in urban as well as in countryside areas are crucial.

Key words: *Carbon pools, North Western Himalayas, Soil organic carbon, Urbanization.*

Introduction

As urbanization and population growth have progressed rapidly, urban land use patterns have changed dramatically affecting soil environments around the city and its surroundings in a significant way (Xia *et al*., 2017). Temporal and spatial dynamics of soil organic carbon (SOC) in topsoil have been a major concern for the past four decades due to changes in land use and land management (Wang *et al.* 2020). Land use changes have increased exponentially in response to population growth and economic development, leading to large changes in soil carbon stocks that directly or indirectly impact the global climate (Vasenev *et al*., 2018). Since urban populations are highly concentrated, the urban and surrounding soils become eutrophicated due to an imbalance of nitrogen and phosphorus (Muñoz Rojas *et al.*, 2015; Adhikari *et al.*, 2019). Urban soils are polluted by intensive industrialisation, agricul-

([1]Assistant Prof., [1]Prof. & Head, [2]PhD Scholar, [3]Subject Matter Specialist -Soil Science) tural production, and other human activities. Factory construction, house construction and road construction in cities which in turn altered the soil pore profile, flow of soil water, gas and nutrient concentrations (Wiesmeier *et al.*, 2011).

Organic carbon pools exist in urban soils (Cambou *et al.,* 2018) and is also affected by urbanization directly and indirectly (Zhao *et al.,* 2015; Stumpf *et al.,* 2018). In urban landscapes, it is implied that anthropogenic factors will dominate natural factors when it comes to determining soil organic carbon storage (SOC) (Pouyat *et al.*, 2009). The biggest contributors to atmospheric CO_2 emissions are urban areas, where the perpetuation of soil organic carbon (SOC) can offset carbon losses (Canedoli *et al.,* 2020). Global terrestrial ecosystems store a significant amount of organic carbon (SOC) in their soils. Studies on SOC are generally confined to natural soils or agricultural areas. Only few studies have been conducted in rapidly urbanized areas regarding SOC stocks and their changes (Vasenev *et al.,* 2014). Keeping in view the significance and vitality; this study was carried out with the objective to assess the status of soil organic carbon stock in different urban areas.

Materials and Methods

Study Area

On the southern slope of the Himalayas lies Kangra district, which is the most populous district in Himachal Pradesh, which is a hilly state of India located in the north-western Himalayas. The altitude varies from 500 meters above mean sea level to around 5000 meters above mean sea level in Kangra district, which is positioned between 31 -21° and 32°59° North latitude and 75 - 47°55° East longitude. Snowfall reaches on the Dhauladhar range (lesser Himalayan chain of mountains) on the district's mountain ranges, hills, and valleys. There are four seasons in the district ranging from subtropical to humid. Winter lasts from December to February, while summer lasts from March to June, and July to September are the rainy months. It receives about 1751 mm of average annual rainfall; most of which occurs from June to September. The highest and lowest average temperatures range between 22.50 and 38.77 ^{0}C and 2.40 and 20.40 ^{0}C, respectively.

Soil Sampling and analysis

In order to assess the impact of urbanization on soil organic carbon stock surface soil samples (0-15 cm) were collected from 3 sites namely Dharamshala (Municipal Corporation), Palampur (Municipal Council) and Baijnath-Paprola (Nagar Panchayat). Soil samples were also collected from countryside area (agriculture fields) that represented control. After being collected, soil samples were brought into a soil lab, air dried under the shade, ground in a wooden pestle and mortar, passed through a 2 mm sieve, followed by a 0.5 mm sieve, and then stored in cloth bags. Then the soil organic carbon was determined. A metallic core with an internal diameter of 8 cm and an internal height of 11.5 cm was used to determine the bulk density. The core had a sharp edge at one end, allowing easy penetration into the soil, and a 1 cm thick open circular cap that fitted on top of the core. A hammer was used to drive the core into the ground. Soil organic carbon was estimated by using rapid titration method (Walkley and Black, 1934) and bulk density was analysed by using core method(Blake and Hartge, 1986). Soil carbon stock (Mg C ha^{-1}) was calculated by multiplying soil organic carbon (%) with soil bulk density (Mg m^{-3}) and soil depth (cm) as following formula outlined by Nelson and Sommers.

Soil Organic Carbon stock = Soil bulk density (Mg m^{-3}) x Soil depth (cm) x Carbon (%)

Results and Discussion

The perusal of the data (Table 1) revealed that bulk density varied significantly among different urban areas and their countryside area. Among different urban areas, the highest bulk density (1.36Mg m^{-3}) was recorded in Nagar Panchayat followed by Municipal Council (1.32 Mg m^{-3}) and Municipal Corporation (1.30 Mg m^{-3}). The bulk density at countryside area is significantly lower than the bulk density recorded in urban areas. Among countryside areas, the highest bulk density (1.20 Mg m^{-3}) was

Table 1. Status of soil bulk density (Mg m^{-3}) in different urban areas

Urban Areas	Bulk Density (Mg m^{-3})
Municipal Corporation	1.30
Dharamshala Countryside	1.18
Municipal Council	1.32
Palampur Countryside	1.20
Nagar Panchayat	1.36
Baijnath Countryside	1.19
CD (P< 0.05)	0.10

recorded in Palampur countryside followed by Nagar Panchayat (1.19 Mg m^{-3}) and Municipal Corporation (1.18 Mg m^{-3}).

The higher value of bulk density in the soils can also be ascribed to lower soil organic carbon content. These findings are in the line with Bhardwaj *et al.* (2013) who reported higher bulk density in soil that have lower organic carbon content. Bulk density in urban areas is higher than the countryside area which might be due to compression in urban areas due to higher flux of people and vehicles. In countryside area the major part of land is under agriculture and the lower bulk density in upper layer of soil profile may have resulted from the dilution of soil matrix (mineral matter) with lesser denser material (organic matter) and improvement in soil aggregation. Improvement in aggregation encouraged fluffy and porous conditions in soil which resulted in lower bulk density.

It is evidently clear from the data (Table 2) that soil organic carbon (OC) was significantly varied in different urban areas. The highest organic carbon (1.36%) was reported in Municipal Corporation followed by Municipal Council (1.20%) and Nagar Panchayat (1.09%). The organic carbon content was significantly lower in countryside area than the OC content in their respective urban areas but the trend was similar as of urban areas. Among countryside areas, the highest organic carbon (1.01%) was reported in Municipal Corporation followed by Municipal Council (0.90%) and Nagar Panchayat (0.82%). The higher OC content in Municipal Corporation Dharamshala owed to its higher altitude which can be owed to continuous accumulation of leaf litter and slower decomposition rate at the higher altitude than at lower ones. Slower decomposition means less mineralization and hence losses of organic carbon through erosion will be lower at higher altitude and hence more carbon content conservation. The carbon fixed by the plant is the primary source of organic matter input into the soil, which provides substrate for microbial process and accumulation of soil organic matter. The belowground allocation of photosynthates is also an important factor for improving soil organic carbon content. The greater accumulation of soil organic carbon on the surface is due to the incorporation of leaf litter. Organic carbon content is affected by leaf litter, higher rate of turnover of minute rootlets death and decomposition of roots and exudation of organic chemicals. The higher OC content in urban areas as compared to countryside area might be due to untapped OC in urban areas and tree based system which increases OC due to more leaf litter deposition and root turnover from trees. These findings were in line with the results obtained by Koul and Panwar (2012), Arora *et al.* (2014) and Bhardwaj *et al.* (2013). OC content in urban soils was found significantly higher as compared to countryside area that might be due to the loss of soil OC from arable land as a result of erosion of carbon-rich topsoil and increased carbon oxidation associated with tillage, and modern agricultural practices such as greater fertilizer use (Ciais *et al.*, 2010; Sun *et al.*, 2011 and Edmondson *et al*,. 2012).

It is evident from the data (Table 3) that soil carbon stock was significantly varied among different urban areas. The highest soil carbon stock (26.48 Mg C ha^{-1}) was recorded in Municipal Corporation which was significantly higher than Municipal Council (23.84 Mg C ha^{-1}) and Nagar Panchayat (22.24 Mg C ha^{-1}). The soil carbon stock in Municipal Council is numerically higher but statistically at par with the soil carbon stock in Nagar Panchayat . Among countryside areas the highest soil carbon stock was found in Municipal Corporation (17.92 Mg C ha^{-1}) followed by Municipal Council (16.30 Mg C ha^{-1}) and Nagar Panchayat (14.72 Mg C ha^{-1}).

Table 2. Status of soil organic carbon (%) in different urban areas

Urban Areas	Organic Carbon (%)
Municipal Corporation	1.36
Dharamshala Countryside	1.01
Municipal Council	1.20
Palampur Countryside	0.90
Nagar Panchayat	1.09
Baijnath Countryside	0.82
CD (P< 0.05)	0.16

Table 3. Status of soil organic carbon stock (Mg C ha^{-1}) in different urban areas

Urban Areas	Soil Carbon Stock (Mg C ha^{-1})
Municipal Corporation	26.48
Dharamshala Countryside	17.92
Municipal Council	23.84
Palampur Countryside	16.30
Nagar Panchayat	22.24
Baijnath Countryside	14.72
CD (P< 0.05)	3.86

Although the soil carbon stock among countryside areas was statistically alike. Higher soil carbon stock in Municipal Corporation was associated with the bulk density and organic carbon content of the soil of particular urban areas. The higher amount of soil organic carbon stock may be explained in the sense that there is continuous accumulation of leaf litter on the surface which keeps on decomposing and thus enriches the upper layer continuously. Moreover the lower temperature in Municipal Corporation also leads to slow decomposing rate. The abundant litter and/or pruned biomass returns to soil, combined with the decay of roots contribute to the improvement of organic matter. Low amounts of soil carbon stocks under the countryside (agriculture land use system) could be ascribed to intensive cropping Bhardwaj *et al.* (2013). Urbanization is widely presumed to degrade ecosystem services, but empirical evidence is now challenging these assumptions. Higher urban soil OC storage than in regional agricultural land at equivalent soil depths was also reported by Edmondson *et al.* (2012).

Conclusion

The idea that urbanization degrades ecosystem services has long been accepted, but empirical evidence is rapidly challenging this view. Soil carbon stock was higher in urban areas than the countryside area. At equivalent soil depths, the soil carbon pools in urban soils was significantly higher than in countryside areas. In order to achieve sustainability, it is essential to gain a better understanding of fundamental ecosystem functions, because urban ecosystems may have implications for land-use plans and policies as a result of SOC inventories, especially in densely populated regions. Therefore, to achieve effective management of urban soils, accurate assessments of ecosystem carbon stocks are necessary and efforts should be made to improve the accuracy of carbon stock estimates.

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Conflict of interest. The authors declare that there is no conflict of interest.

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